ASME AG-1 SECTION FI EXPERIENCES

by

L.D. Weber
TechMark Corporation, 52 Fourth Street,
Holbrook, NY 11741, USA.

ABSTRACT

Metallic filters may withstand high levels of moisture, temperature, and pressure differential/transients. They may also be cleaned for re-use by procedures substantially reducing occupational exposure and solid waste accumulation.

Draft Section FI is in coordination for publication in The American Society of Mechanical Engineers (ASME) AG-1 Code, and is scheduled for second ballot by the Main Committee of the Committee on Nuclear Air and Gas Treatment (CONAGT). This Section provides requirements for the performance, design, construction, acceptance testing, and quality assurance of filters comprising metal media that are used in nuclear safety related air and gas treatment systems.

This paper overviews key features of Section FI and highlights several significant changes resulting from the Main Committee's first ballot.

New directions in ASME Code preparation for metal filters are also contemplated, potentially to address products performing outside the present effort's focus on high efficiency, and/or those operating at higher operating pressure differentials. Potential *venues* may include preparing a new AG-1 Code Section, incorporation into Section FK, or preparing a subsequent Revision to Section FI. Ceramic and/or other high strength materials used in filter media may also be addressed pending further review.

INTRODUCTION

Background:

Filters of stainless steel filter media are attractive in a number of applications due to their strength, durability, moisture resistance, temperature resistance, potential for cleaning and re-use (occupational exposure and radioactive waste volume reduction) and, in some cases, their chemical properties. Additional types of metal alloys and composites may also be attractive in particular applications.

Most commonly, metal filter medium is prepared from sintered or non-sintered woven wire mesh, metal fibers (*e.g.* metal "paper"), sintered metal powder, and/or combinations of these forms of materials.

The TMI event (1979) and the Chernobyl accident (1986) stimulated commercial development of all metal filters suitable for reactor containment pressure relief (Dillman and Wilhelm, 1990; Kaercher, 1992; Randhahn, 1988). A technologic prompt to seeking mitigation of reactor containment pressures by the application of metal filters was the availability of stainless steel fibers in such diameter as could be used to prepare metal filter media with a lower resistance to airflow at a given filter efficiency than media prepared exclusively with the sintered powder technology then commercially established.

In addition, the aerodynamics and physics of particle removal by filter media prepared of glass and/or cellulose fibers had been thoroughly studied and applied in the field; and the particle removal behavior of fiber-metal filter media utilizing fiber diameters similar to that of glass and/or cellulose offered a new material presenting highly analogous filtration mechanisms.

Metallic filters have since been widely employed in France, Germany and other European countries in containment venting, and have been examined extensively on behalf of a variety of applications in the U.S., including those calling for low pressure drop and for efficiency of ≥99.97% or better at 0.3 micrometer or most penetrating particle using dioctyl phthalate smoke (Bergman et al, 1990; Bergman et al 1996, Bergman et al 1992; Burns et al, 1996; Weber, 1990; Weber and Whitlock, 1992, Weber et al, 1996; Wilhelm, 1996). Applications in the U.S. have involved principally those associated with the Department of Energy and its site cleanup program, such as tank ventilation, waste vitrification, ablation processes, and others.

Purpose:

Both government-formulated and engineering Consensus Codes and Standards, designed to define and maintain performance characteristics and reliability of filters shipped to end-users, comprise important tools to sustaining public safety during operation and maintenance of nuclear and non-nuclear facilities. They further provide users an oversight means for new products in development.

ASME, through CONAGT, has undertaken to prepare and publish a Code enabling users of ASME's Code On Nuclear Air and Gas Treatment (AG-1) to specify filters of metallic porous material ("metal media filters").

This initial/current ASME Code effort in metal media filters, designated AG-1 Section FI, focuses upon operating pressures accessible to blower-actuated air and gas streams, and upon filters of high efficiency porous media comprising stainless steel alloys.

The purpose of this report is to provide an update on recent review experience with Section FI, to highlight its major features, its modifications now in coordination, and to summarize the prospects for future directions in ASME Code for metal filters. A comprehensive summary of the provisions of Section FI was earlier prepared, and is available in the Proceedings of the 8th ASME/JSME International Conference on Nuclear Engineering (Weber, 2000).

KEY FEATURES OVERVIEW OF CODE SECTION FI

Definition And Scope:

An air and gas cleaner, referred to as "HEMA," is defined as a high efficiency metal air filter, comprising metal filter medium encased in rigid hardware. (Note: The name HEMA, although superficially analogous to a well-known acronym, is not of itself intended as a direct acronym.)

Section FI of the AG-1 Code is of the following Scope: "This section of the Code provides requirements for the performance, design, construction, acceptance testing, and quality assurance of metal medium filters used in nuclear safety related air and gas treatment systems."

A comprehensive set of parameters are specified by Section FI, together with examples of acceptable HEMA filter geometries. Section FI does not cover integration of filters into air or gas cleaning systems, nor systems for regenerating filters, even while requiring specific qualification testing for cleanable filters.

HEMA Filter Geometries:

The following definitions form the basis of broad geometric acceptability under FI.

1. Filters may be built up of basic units defined as modules: "*filter module* - smallest unit of filter construction. Comprises filter medium sealed to supporting hardware. In some designs, modules may be of a configuration also conforming to the definition of an element."

   An *example* of a filter module is shown as Figure 1.

2. Modules may be assembled into or utilized as filter elements: "*filter element* - an individual or assembly of modules designed for attachment to a tube sheet or other housing internals. A filter element may present a tubular, pleated, square, or rectangular surface to flow."

   Element construction allows for higher flow rate assemblies and/or bundling into systems of the desired aspect ratio or footprint. N.B. the range of acceptable cross-sectional geometries for modules and elements is very wide. An *example* of a HEMA element assembly in a pressure vessel is provided as Figure 2.

3. Panel geometries are also acceptable: "*panel* - a filter geometry in which filter medium and/or elements are sealed to a case that is rectangular or square in the crossection it presents to flow."

An *example* of a panel constructed of HEMA elements is provided as Figure 3. Bergman et al (1994) published information about a prototype embodiment of the type of construction depicted schematically in the Figure 3 example.

Thus, FI is non-restrictive of filter geometry and filter medium construction. Simple-cylinder or pleated cylindrical filters are acceptable, as are other geometries, packaged singly or bundled together, and/or packaged in filter housings configured for self-cleaning. Also acceptable are single filters bundled together or sheets of metal media fabricated into panels of outer dimensions, and flow ratings familiar to glass fiber users. FI permits metal medium filters to exhibit a maximum clean pressure differential of 2.5" wg. at rated maximum flow.

HEMA Filter Construction:

Three types of filters are addressed:

Type A: all metal construction - This type is applicable to air streams at temperatures to 750°F (399°C) continuous.

Type B: all metal welded construction - This type is applicable to air streams at temperatures to 750°F (399°C)

Type C: Filters in which the metal medium seal to hardware is by potting, such as by epoxy. There are three kinds of Type C filters:

Type C-1: wherein a urethane potting compound is used applicable to air streams at temperatures to 250°F (121°C).

Type C-2: wherein an epoxy potting compound is used applicable to air streams at temperatures to 350°F (177°C).

Type C-3: wherein a silicone potting compound is used applicable to air streams at temperatures to 550°F (288°C).

This Section does not cover integration of filters into air or gas cleaning systems, nor systems for regenerating filters.

HEMA Filter Performance:

Efficiency:

"The filter shall exhibit a minimum efficiency of 99.97% at most penetrating particle diameter, or as measured by penetrometer, when tested with an aerosol of essentially monodispersed 0.3 micron test aerosol particles."

Consistent with this, the definition of penetrometer allows for laser particle counting to be selected, or polarization angle based methods: "*penetrometer* - a device for generating essentially monodisperse test aerosol and for evaluating the aerosol penetration and air resistance of fabricated HEMA filters. A Q76 or Q107 penetrometer, with or without additional laser particle counting equipment, is an example of a suitable penetrometer."

The definition of "test aerosol" provides a benchmark for particle size distribution, but refrains from specifying a material: "*test aerosol* - dispersion of particles in air containing 80 ±20 micrograms per liter of particles 0.2 to 0.3 micrometers dia. at $\sigma_g<1.3$."

Pressure Drop:

At rated flow, clean pressure drop shall be no greater than 2.5" w.c. (625Pa). At terminal pressure drop in service, the HEMA filter is either cleaned for re-use or decommissioned.

Design Qualification:

A qualification sample of 2 of each size HEMA module or panel shall be manufactured using the same methods, materials, equipment, and processes as will be used during production. The test sequence is given in overview as Table 1. The 2 filters used in the qualification sample shall be run sequentially through all these tests, and failure of any filter to comply with the requirements of this section shall be cause for the rejection of the qualification sample.

Tensile Strength of Media:

The influence of media tensile strength and elongation on the performance of an assembled module or filter is governed by the design and construction methods employed. Section FI of the Code is not intended to specify construction methods--many of which may be proprietary to an individual vendor and/or utilize multiple heat treatments and/or rely on the ability of filter media to withstand welding or brazing.

Recognizing the possibility or likelihood of changes to filter media properties during filter construction, the Code specifies simply: "Media successfully used to qualify filter design in accordance with this code shall be deemed qualified on tensile strength." This also means that a change in filter media employed requires re-qualification of a design.

Cyclic fatigue testing of cleanable assembly designs:

Those HEMA filters/assemblies designed for repeated cleaning cycles shall be further qualified by an additional procedure summarized as follows.

1. The filter shall be subjected to an initial aerosol penetration test.

2. The filter (either clean or laden with a contaminant) shall then be exposed at maximum rated continuous temperature to sufficient airflow to generate maximum rated pressure drop.
3. The filter shall then be subject to cleaning (with flushing and drying as applicable) by the procedure specified by the manufacturer, or as agreed to by the manufacturer and owner or engineer. Recovery differential shall be measured at rated flow.
4. Steps 2 and 3 shall be repeated cyclically as applicable. Where a high number of rated cycles makes this impractical, pressure pulsation fatigue testing with the filter submerged in the cleaning fluid may be substituted.
5. A repeat aerosol penetration test successfully passed shall conclude this sequence.

DISCUSSION AND MODIFICATIONS RESULTING FROM MAIN COMMITTEE FIRST BALLOT AND ASSOCIATED COMMENTS

1. <u>Design Specification:</u> Normally part of a procurement process, an explicit requirement was added to FI-4100, "General Design," for users to prepare a functional design specification for a given installation:

"A Design Specification shall be prepared by the owner or engineer in sufficient operating detail to provide a complete basis for equipment design in accordance with this Code, including at minimum the temperature, pressure, and flow ranges of equipment operation. The chemical nature of solids, gases and liquids to which equipment internals and externals are to be exposed shall also be identified."

2. <u>Seismic Testing Requirements:</u> Integration with and references to AG-1 Section AA seismic testing requirements were completed.

3. <u>Qualification Test Operation:</u> A first-ballot Negative by a Main Committee member, raised additional discussion concerning what entities shall be considered "certifiably qualified, independent facilities" permitted to perform design qualification testing. There are presently no facilities known to FI Subgroup members, outside of vendor laboratories, where equipment currently exists that is capable of fulfilling the maximum-temperature/ maximum-pressure loading, and cyclic fatigue testing required.

Therefore, with further input from several Main Committee members, the Subgroup has put forward for consideration and ballot the following statement in Section FI regarding requirements for entities permitted to perform the qualification testing of new or revised filter designs: "Testing must be performed at certifiably qualified, independent facilities; or in-house by a manufacturer maintaining an NQA program."

4. Design Qualification Requirements Based Upon Size: Section FI had required design qualification for each size of filter module or panel, based upon experience that different sizes of metal filters in the same "product line" may nevertheless be constructed differently on account of weight and/or manufacturing differences. In response to first-ballot comments, this technical position was modified by the addition of the following text to the Qualification Testing subsection, FI-5100:

> "Qualification of a filter design qualifies all filters with a lower flow rate provided the lower flow rate design is geometrically similar and manufactured using the same methods, materials, and equipment."

5. Future Directions: A broadening of ASME Code writing activity is contemplated to encompass less efficient metal filters and/or metal filters which can be operated under pressure differentials higher than those produced in fan-actuated systems. Venues for this may be as a subsequent Revision to FI, incorporation in FK or alternatively as a new section. Additionally, filters of ceramic media and/or other high strength materials may also be addressed. DOE site tests of filters in these operating and materials categories have been most recently reported by Adamson (2002).

Due to the characteristics of such filters, Code writing in this area going forward may take into account a spectrum of requirements not previously addressed. Therefore, and affirming FI's Scope, the following text was added to FI-1120, "Applicability:"

"The user is cautioned that application of filters of metal medium not conforming to the definitions and specifications herein may require additional qualification and/or other testing and/or manufacturing requirements not addressed within this Section. Such additional testing may include, for example, the use of test aerosol(s) not herein defined, compatibility testing with chemically active/inactive precoat materials, and/or may require non-aerosol damage/integrity testing not herein defined or specified."

Photographic examples of industrial metal filter modules and elements are shown as Figure 4 for illustration. Similarly, examples of a filter element assembly and housing designed for *in situ* reverse-flow cleaning for re-use are shown in Figure 5. (Neither the presence nor absence of an example or vendor, nor the order of presentation of these Figures, signifies any endorsement or lack thereof.)

CONCLUSIONS

Several salient features of draft ASME AG-1 Code Section FI in coordination are of immediate interest to end-users and vendors, and are summarized as follows.

1. It is non-restrictive with respect to filter geometry and metal medium manufacturing method, provided the performance and qualification requirements are met.

2. It requires structural qualification to demonstrate a filter design can withstand its cleaning procedures to the maximum rated cycles, after cyclic exposure to maximum rated pressure drop and temperature.
3. It requires a maximum clean pressure drop of 2.5" w.c., reflecting the life expectancy, cleanability, and in some cases high area of metal filters for fan-actuated or similar operating environments.
4. It requires filter efficiency of 99.97% at most penetrating particle diameter, or as measured by penetrometer.
5. The test aerosol may be DOP or any other material meeting the test aerosol definition.

Field application of metal media filters in accordance with the performance and qualification requirements is expected to reduce risk to the public from radiation release, reduce risk to the plant worker from potentially hazardous or toxic materials, and reduce radioactive waste accumulation. Code Section FI also provides manufacturers substantial design freedom, provided the Code's performance and qualification requirements are met.

REFERENCES

Bergman, W., Conner, J., Larsen, G., Lopez, R., Turner, C., Vahla, G. Violet, C. And Williams, K., 1990, "High Efficiency Steel Filters for Nuclear Air Cleaning," 21st DOE/NRC Nuclear Air Cleaning Conference.

Bergman, W., Larsen, G., Lopez, R., Wilson,K. , Witherell, C. and McGregor, M.,1996, "Further Development of the Cleanable Steel Hepa Filter Const/benefit Analysis , and Comparison with Competing Technologies," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Bergman, W., Larsen,G., Weber, F., Wilson, P., Lopez, R., Valha, G., Conner, J., Garr, J., Williams, K., Biermann, A., Wilson, K., Moore, P., Gellner, C. and Rapchun, D., 1992, "Development and Evaluation of a Cleanable High Efficiency Steel Filter," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Burns, D.B., Wong, A. Walker, B.W. and Paul, J.D., 1996, "Testing cleanable/reusable HEPA prefilters for mixed waste incinerator air pollution control systems," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Dillman, H.-G. And Wilhelm, J.G., 1990, "Investigations into the Design of a Filter System for Pwr Containment Venting," 21st DOE/NRC Nuclear Air Cleaning Conference.

Kaercher, M.V., 1992, "Design of a Prefilter to improve radiation protection and filtering efficiency of the containment venting system," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Randhahn, H., 1988, "The Development of All-Metal Filters for Use in the Nuclear Industry," Proc. 20th DOE/NRC Nuclear Air Cleaning Conference.

Weber, L.,D., 1990, "Technical Brief: Stainless Steel Filters for Nuclar Air Cleaning,"21st DOE/NRC Nuclear Air Cleaning Conference.

Weber, L.D. and Whitlock, M.B., 1992,"Efficiency Test for Ultra High Efficiency Metal Air Filters," Proc. 22nd DOE/NRC Nuclear Air Cleaning and Treatment Conference,

Weber, L.D., Rahimi, R. and Edling, D., 1996, "Validation testing of an all metal filter for radioactive waste drums," Proc. 24th DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Wilhelm, J.G., 1996, "Provisions for Containment Venting in Germany," Proc. 24th Nuclear Air Cleaning and Treatment Conference.

Bergman, W., Larsen, G., Lopez, R., Wilson,K. , Simon, K., and Frye, L.,1994, "Preliminary Field Evaluation of High Efficiency Steel Filters," Proc. 23rd DOE/NRC Nuclear Air Cleaning and Treatment Conference.

Weber, L.,D., 2000, " High Efficiency Metal Filters For Nuclear Air And Gas Treatment: "HEMA" Filters And Their New AG-1 Code Section," Proc. 8th ASME/JSME International Conference on Nuclear Engineering.

Adamson, D.J, Terry, M.T, and Burns, D.B., 2002, "In Situ Cleanable Alternative HEPA Filter Media," Proc. ANS Spectrum Conference on Nuclear and Hazardous Waste Management.

TABLE 1
TESTGROUPS AND SEQUENCE

Group	Qty*	Requirement	Test Paragraph
I	2	Resistance to rated airflow	FI-5110
		Test aerosol penetration at rated airflow and at 20% of rated airflow	FI-5120
		Resistance to pressure	FI-5140
		Resistance to rated airflow	FI-5110
		Test aerosol penetration rated airflow only.	FI-5120
II	2	Resistance to rated airflow	FI-5110
		Test aerosol penetration at rated airflow and at 20% of rated airflow	FI-5120
		Resistance to rough handling	FI-5130
		Resistance to heated air	FI-5150
		Resistance to rated air flow	FI-5110
		Test aerosol penetration at rated airflow only	FI-5120
III	2	This section applies to Type C devices only.	
		Resistance to spot flame	FI-5160
IV	2	Resistance to rated airflow	FI-5110
		Filters subjected to rated airflow with water spray (MIL-F-51068). Pressure drop across clean filter not to exceed 5 times rated dry pressure drop.	TABLE FI-5100-2
		Test aerosol penetration at rated airflow after drying.	FI-5120

*Note: Two filters, as described in Section FI-5100, shall be tested sequentially through all applicable groups.

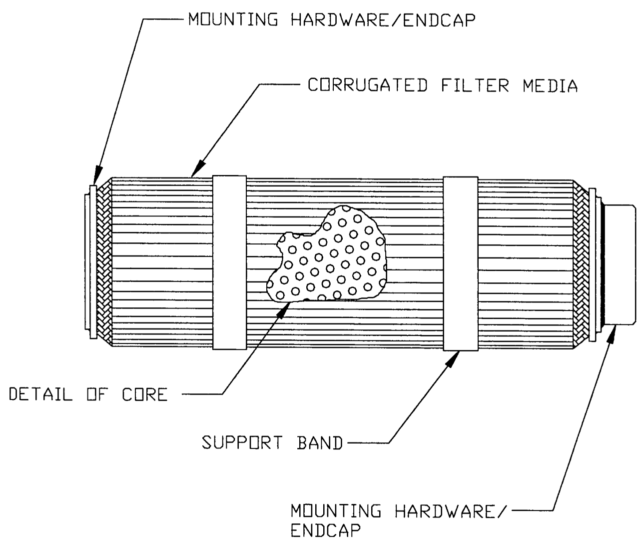

Figure 1. Example of HEMA module.

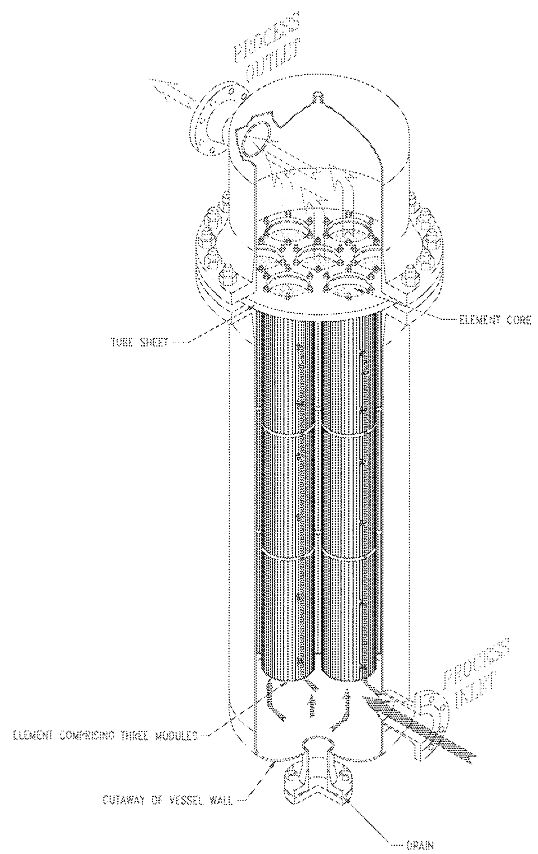

Figure 2. Example of HEMA element assembly in pressure vessel.

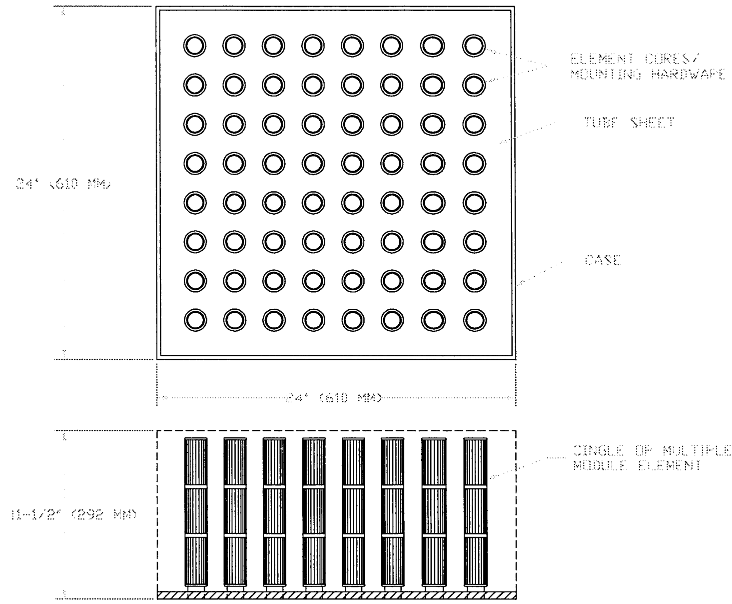

Figure 3. Example of panel constructed of HEMA elements.

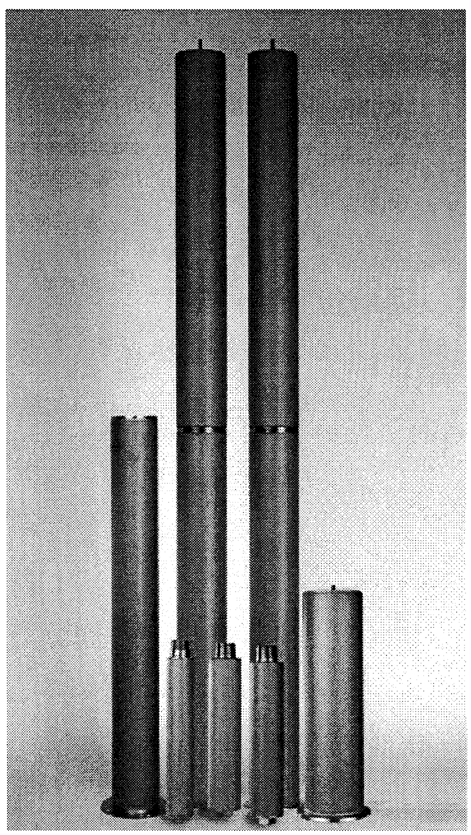

Figure 4. Examples of industrial metal filter modules and elements (Courtesy of Bekaert Corporation, Research Triangle Park, NC, USA.)

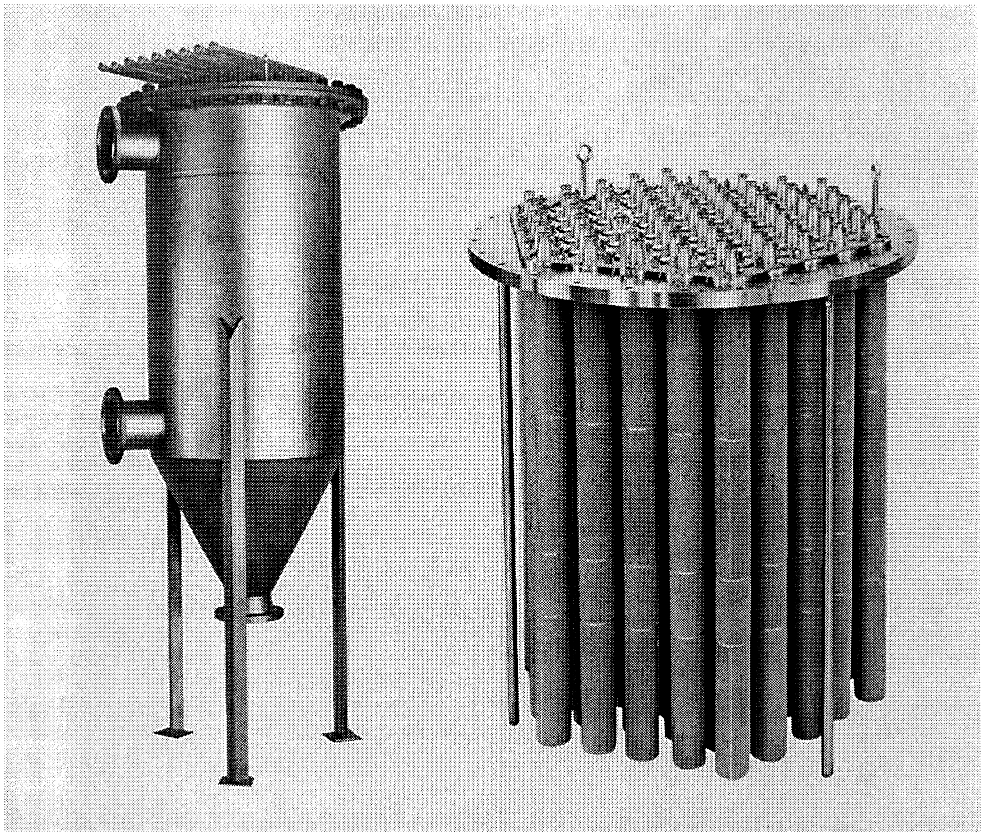

Figure 5. Examples of a filter element assembly and housing designed for *in situ* reverse-flow cleaning for re-use (Courtesy of Mott Corporation, Farmington, CT, USA).

With a Ph.D. in physical chemistry, Larry Weber began his career in research as a Post-doctoral Fellow at MIT. He subsequently transitioned to applied sciences and engineering during a 15 year stint with Pall Corporation. There, he also became very active in technology transfer and intellectual property strategy. Leaving Pall in 1998 to pursue these interests, he currently works with corporate and government-backed collaborators in asset tracking, anti-counterfeiting technologies, Internet-linked wireless sensors, and independent porous materials research.